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THE APPLICATION OF AERO-HYDRAULIC GUNS TO BIOLOGICAL WASTE TREATMENT SYSTEMS IN THE PROVINCE OF ONTARIO

REPORT ON

THE APPLICATION OF

AERO-HYDRAULIC GUNS

TO BIOLOGICAL WASTE TREATMENT SYSTEMS

IN THE PROVINCE OF ONTARIO

By:

J. W. G. Rupke

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

In the past, the OWRC has investigated the aeration device known as the "Aero-Hydraulic bubble gun". The studies to date have centred around the oxygen transfer capacity of these units. Thon (1) indicated that under process conditions of 15 ft of depth, the guns were capable of transferring .72 lb O_2/hr/gun at an air supply of 16.5 scfm. Under these conditions, the manufacturer claimed the transfer capacity to be 1.1 lb O_2/hr/gun.

Routine monitoring of the existing systems which employ the manufacturer's oxygen transfer capacity for design have shown that frequently the effluent from these systems does not meet the biochemical oxygen demand (BOD) and suspended solids requirements as set down by the OWRC. As a result of a Division of Industrial Wastes request, this study was carried out to evaluate all biological waste treatment systems employing the Aero-Hydraulics gun in the Province of Ontario.

EXPERIMENTAL PROCEDURE

In the Province of Ontario, there are ten biological waste treatment installations using Aero-Hydraulic guns. They range in complexity from a simple aerated lagoon to an extended aeration activated sludge plant.

Each installation was visited and if there was insufficient data available, a biological waste loading survey was carried out. This survey supplied additional data such as waste flows, nutrients available, pH characteristics and suspended solids. The effluent quality was also simultaneously investigated. On several systems, the effluent quality was monitored over an extended period of time.

An attempt was made to determine the oxygen transfer capability of the gun by measuring the respiration rate of the aerated media under steady-state conditions. Dissolved oxygen (DO) and temperature surveys were conducted at various times, and a sludge depth probe was used to determine the depth of the sludge deposited on the bottom of the aeration zone.

Measurements were made at all lagoon sites to verify the design drawings. General comments were recorded regarding the mechanical operation of the guns as well as the smell and appearance of the treatment facility.

GENERAL DESCRIPTION OF INSTALLATIONS

There are only two installations in Ontario which can be classed as true aerated lagoons. One is a five-acre lagoon, treating the waste from a potato processing plant owned by Salada Foods Ltd. in Alliston. In this lagoon, the guns are slightly concentrated at the inlet end. The effluent is discharged to two stabilization ponds operated in series. The present aerated portion of this system was originally designed as an anaerobic lagoon. However, the odour problem which developed forced the Company to add 127 Aero-Hydraulic guns to convert it to an aerobic lagoon. The liquid depth of this lagoon is 9 ft, as compared to the recommended minimum of 14 ft liquid depth, if Aero-Hydraulic guns are to be used for aeration. This, coupled with an over-estimation of the aeration capacity of the guns, led to poor treatment efficiency from this system.

The second aerated lagoon treats poultry processing wastes from Skyline Farms Limited in Kettleby. This installation has been investigated by Boyko (2).

A modification of the aerated lagoon design divides the system into an extended aeration zone using a crude means of sludge return followed by a polishing zone. At Cochrane,

the municipal waste is treated with such a system. An identical system at Chesterville treats the waste from Nestle's instant coffee production. The modified design incorporates a V-shaped clarifier for sludge return. This clarifier is either affixed to solid wingwalls which complete the barrier from shore to shore or transverses the entire width of the lagoon.

The same design parameters can be incorporated into a concrete or steel tank design, as has been done in the Sudbury area where the International Nickel Company of Canada Ltd. has three systems treating domestic and shower-house wastes.

Domestic waste is treated at Lively and Levack, where an additional clarification zone was incorporated into circular steel tank design.

The physical dimensions and associated mechanical information for all these systems are found in Table I.

TABLE I

MECHANICAL DETAILS

LOCATION	AERATION ZONE L ft	W ft	D ft	Volume 1,000 ft^3	# Guns (r) return (d) directional	# Guns aeration	POLISHING ZONE Volume 1,000 ft^3	# Guns aeration	CLARIFIER Area ft^2	AIR SUPPLY scfm	scfm/gun
Salada Foods Ltd.	850	280	9	1,700	-	127	-	-	-	780	6.15
Skyline Farms Ltd.											
Actual	280	180	15	525	9 (d)	30	-	-	-	325	8.33
Proposed	78	180	15	131	4 (d) 4 (r)	23	394	8	176	325	8.33
Nestle's (Canada) Ltd.	85	136	15	115	17 (d)	36	360	7	400	750	12.5
Cochrane	105	150	15	130	13 (d)	42	500	6	300	820	13.4
Winona	287	163	15	517	13 (r)	98	258	6	2940	1640	14.0
Stobie Mine	25	48	16	19.4	9 (r)	15	-	-	300	460	19.1
Frood Mine	35	660	16.5	35.7	12 (r)	24	-	-	510	720	20.0
Murray Mine	38	16.5	15	9.0	3 (r)	6	-	-	124	200	22.2
Lively	*	*	15	73.9	12 (r)	42	-	-	745	540**	10
Levack	*	*	15	59.2	10 (r)	43	-	-	884	540**	10

* Lively and Levack are circular tanks with the aeration section in the outside ring, the clarifier in the middle ring and the final clarifier in the centre portion.

** Estimated air supply

RESULTS

A. SPECIFIC INSTALLATIONS

Salada Foods Limited (Alliston)

In the past, Salada Foods Limited in Alliston treated 750,000 gallons of potato processing wastes/day (BOD 1,200 mg/l) in a 1,700$\times 10^3$ cu ft lagoon designed to handle approximately one-third of this biological load. The lagoon was aerated by 127 Aero-Hydraulic aeration guns. During the processing season, this aerobic lagoon seldom contained a measurable amount of DO. As a result, the effluent quality suffered severely.

The company has recently installed a pretreatment facility to reduce the biological load to the aerated lagoon.

When the pretreatment works were being installed, the lagoon was also renovated. It was found that there were 2-3 ft of compacted sludge accumulated at the influent end of the lagoon.

Skyline Farms Limited (Kettleby)

Skyline Farms Limited at Kettleby is a chicken processing plant producing 180,000 gal of waste flow per day. The waste, with an average BOD of 600 mg/l, is treated in a 525,000 cu ft aerated lagoon. The system employs 30 Aero-

Hydraulic aeration guns, chiefly concentrated in the first one-half of the lagoon. There are also 9 directional guns which were designed to produce a "hydraulic barrier" as well as providing aeration.

This system was designed to treat 750 lb BOD/day and it has been receiving 920 lb BOD/day.

Over the past several years, the average effluent BOD has increased from 50 mg/l to 85 mg/l. A recent sample showed 185 mg/l BOD and a suspended solids (SS) of 345 mg/l in the effluent. At all times, there has been ample DO at the surface of this lagoon. There is indication that solids are depositing on the bottom.

Town of Cochrane

The Cochrane municipal sewage is treated in a 630,000 cu ft aerated lagoon designed to treat 1,200 lb BOD/day at a hydraulic load of 600,000 gallons per day (gpd).

The lagoon is separated into two zones by a barrier wall of steel and transite and a V-shaped polyethylene clarifier 60 ft long. The first, or extended aeration zone, has a volume of 130,000 cu ft and is aerated by 42 Aero-Hydraulic aeration guns. In addition to the aeration guns, there are 13 directional guns, some of which are used to return sludge

from the clarifier. This sludge is returned to the effluent end of the extended aeration zone. The second or polishing zone has 6 aeration guns in a volume of 500,000 cu ft.

At the time of investigation (one week after spring breakup), the raw sewage BOD's averaged 42 mg/l at an estimated flow of 500,000 gal/day. The effluent BOD was 15 mg/l and had a SS of 50 mg/l. The mixed liquor suspended solids (MLSS) was 300 mg/l.

Earlier investigations by others (3) and routine analysis of grab samples show an average raw sewage BOD of 145 mg/l and a SS of 120 mg/l at a flow of 500,000 gal/day. The calculations incorporated into this report are based on this latter average BOD value, which is more representative.

Raw sewage pH recording at this facility showed a considerable rise in pH at fixed times each day. The pH values normally were in the range of 7.2 to 7.8. However, several times each day, the pH would rise to 8.5 to 9.4 for periods of an hour or more. This pH rise was attributed to periodic discharges of caustic by both the dairy and soft drink bottling works.

Considerable settled sludge has accumulated both in the aeration and polishing zones. It was estimated that approximately 30 percent of the lagoon volume was occupied by settled sludge of 3.5 percent suspended solids.

E. D. Smith & Sons Limited (Winona)

E. D. Smith and Sons Limited in Winona have a 775,000 cu ft aerated lagoon designed to treat a biological waste load of 2,625 lb BOD/day at a hydraulic flow of 375,000 gpd.

This company processes cherries, tomatoes, and apples progressively as these fruits mature during the growing season.

The lagoon is separated into two sections by a transite and steel V-shaped clarifier. The first, or aeration zone has a volume of 517,000 cu ft and is aerated by 98 Aero-Hydraulic aeration guns. In addition to the aeration guns, there are 13 sludge return guns designed to return sludge from the bottom of the clarifier to the influent end of the lagoon. The second one is a polishing zone of 258,000 cu ft with 6 aeration guns.

When the investigation began, the tomato processing season had just ended and the apple processing had started. The waste characteristics over the 4-week period are shown on the following page.

	mg/1
BOD	1,900
Filtered BOD	1,660
COD	2,420
Total Kjeldahl as N	12.0
PO_4	19.3
SS	236

This gave a BOD load of 2,640 lb BOD/day on a 5-day basis (Monday to Friday).

During the period of study, the maximum DO in the aeration zone dropped from 8.7 mg/1 to 4.2 mg/1. The corresponding DO's at the effluent weir were 3.4 mg/1 and 0.2 mg/1.

The bottom of the lagoon appeared to have 2-4 inches of solids deposited. The mixed liquor in the aeration zone had a SS content of 50 mg/1 and the effluent SS were 23 mg/1.

During the period of study, the effluent BOD continued to rise from 100 mg/1 to a plateau of 500 mg/1.

Nestle's (Canada) Limited - (Chesterville)

Nestle's (Canada) Limited in Chesterville treat their processing waste in a two-stage aerated lagoon with an overall volume of 475,000 cu ft and designed to treat 300,00 gpd of coffee processing wastes at a BOD of 400 mg/1.

The first stage is an extended aeration zone of 115,000 cu ft using 36 aeration guns and 17 directional guns, to aerate and mix the contents. The second, or polishing, zone has a volume of 360,000 cu ft and uses 7 aeration guns.

Between the two sections, there is a solid baffle of concrete spanning two-thirds the width of the lagoon; the remaining one-third is covered by a V-shaped polyethylene clarifier designed to retain the biological solids in the extended aeration zone. The waste characteristics over the 4-week study are shown below.

	mg/l
BOD	540
Filtered BOD	385
COD	1,070
SS	348
NH_3 as N	1.0
Total Kjeldahl as N	40.6
PO_4	13.6

The average flow and BOD load were 278,000 gpd and 6,340 lb BOD per day respectively.

Over the same period, the effluent quality was as shown below.

	mg/l
BOD	266
Filtered BOD	210
COD	525
SS	89
NH_3	3

The extended aeration zone contained a MLSS of 100 mg/l, and a DO of 4 to 6 mg/l. The DO dropped to 2 mg/l at the effluent end of the lagoon. There was an accumulation (2-4 in.) of settled solids on the bottom of the entire lagoon.

A sample of the waste was taken to the OWRC laboratory and inoculated with ammonia to a concentration of 45 mg/l as nitrogen. This sample, along with a control, was aerated for 20 days. During this period of aeration, the BOD reduction and SS increase showed no significant effect of ammonia addition.

International Nickel Co. of Canada Ltd. (Sudbury)

The International Nickel Company of Canada has installed three Aero-Hydraulic extended aeration systems. The aeration in these systems is accomplished using Aero-Hydraulic aeration guns in a rectangular basin. Along one

side of this aeration zone, there is a sedimentation zone designed to retain the biological solids within the system. The sludge is returned to the influent end of the aeration zone by return sludge guns which draw sludge from the bottom of the sedimentation zone.

All three of these systems are treating a small amount of domestic sewage combined with a large volume of shower-house wastes. They are located at the Murray, Stobie and Frood Mines.

The waste and effluent characteristics are shown below.

	INFLUENT			EFFLUENT		
	BOD	SS	Flow mgd	BOD	SS	MLSS
Stobie	27	138	0.127*	17	30	37
Frood	23	55	0.154	8	23	31
Murray	49	114	0.072	14	42	52

* Design flow (no measuring device available)

The above data is taken from routine samples submitted to the OWRC laboratories.

At all these installations there were 1-2 ft of heavy solids accumulated on the bottom of the aeration tank. The

DO in the aeration tank was always at least 3 mg/l even after the blowers had been off for 10 minutes. All these systems operate the aeration and return guns on a timer cycle. This intermittent operation has resulted in plugging of several guns in each installation.

The Towns of Lively and Levack

The Towns of Lively and Levack both use circular extended aeration plants to treat the municipal wastes. These units are large circular concrete tanks with two inner rings to define the 3 zones. The outer zone is used for aeration; the second zone (or clarifier) is used to separate the biological solids and return these to the aeration zone; the third zone (or sedimentation zone) is used to further reduce the suspended solids in the effluent.

In both installations, the aeration zone had accumulated 1-2 ft of heavy sludge on the bottom of the tank. Even when the air supplies were increased to maximum, these levels were not reduced.

The MLSS at Lively averaged 61 mg/l, and that at Levack was 89 mg/l.

The raw sewage and final effluent characteristics are shown below.

	Influent		Effluent	
	BOD	SS	BOD	SS
Lively	150	180	52	60
Levack	130	162	49	60

The flow at Lively was 127,000 gpd; that at Levack was 167,000 gpd.

The blowers at both of these installations are normally run throttled-back from their maximum output.

B. <u>GENERAL</u>

The biological loadings, effluent qualities and operating parameters of all systems are summarized in Tables II, III, and IV.

An attempt was made to determine the steady-state oxygen transfer capacity at each facility visited. It was found, however, that it was not possible to determine any measurable oxygen uptake rate in the systems investigated.

In all installations, except Cochrane, the MLSS appeared to be of a non-flocculant nature.

With the exception of Alliston, no serious odour problems have been encountered. Skyline Farms Ltd. has reported temporary odour problems several months after spring breakup.

Several of the installations using positive displacement blowers have experienced continuous bubbling on some of the guns.

TABLE II

WASTE AND EFFLUENT CHARACTERISTICS

LOCATION	Raw Waste					Final Effluent		% Removal	
	Flow mgd	BOD mg/l	lb BOD/day	SS mg/l	lb SS/day	BOD mg/l	SS mg/l	BOD	SS
Salada Foods Ltd.	0.750	1200	9000	400	3000	1100	249	8	38
Skyline Farms Ltd.	0.180	600	1080	368	663	85	56	86	85
Nestle's (Canada) Ltd.	0.278	540**	1500	348	968	266	89	51	74
Cochrane	0.500	145	725	120	600	15	50	90	58
Winona	0.125	1900**	2380	236	295	500	25	74	90
Stobie Mine	0.127*	27	34	38	48	17	30	37	21
Frood Mine	0.154	23	35	55	85	7.5	23	68	58
Murray Mine	0.072	49	35	114	82	14	42	72	63
Lively	0.127	150	190	180	228	52	60	65	66
Levack	0.167	130	218	162	271	49	60	71	63

* design flow

** nutrients limiting

TABLE III

MIXING PROPERTIES OF AERO-HYDRAULIC GUNS

LOCATION	Water Discharge from gun ft^3/sec	ft^3 of aeration volume x 10^{-3} per gun		Aeration basin turnover time*	
		aeration guns	aeration plus return guns	aeration guns	aeration plus return guns
Salada Foods Ltd.	2	13.4	-	112	-
Skyline Farms Ltd.					
Actual	2.5	17.5	13.5	117	90
Proposed	2.5	6.25	4.25	41.6	28.3
Nestle's (Canada) Ltd.	2.9	3.2	2.17	18.4	12.4
Cochrane	3.0	3.1	2.36	17.2	13.1
Winona	3.05	5.3	4.65	28.9	25.4
Stobie Mine	3.3	1.29	.81	6.5	4.05
Frood Mine	3.3	1.49	.99	7.5	5.0
Murray Mine	3.4	1.50	1.00	7.35	5.05
Lively **	2.5	1.76	1.37	11.7	9.2
Levack **	2.5	1.38	1.12	9.2	7.5

$$* \text{ Turnover time in minutes} = \frac{\text{aeration volume in cu ft}}{\text{aerator pumpage rate in cu ft/min}}$$

** At maximum blower output

TABLE IV

OPERATING PARAMETERS

LOCATION	AERATION ZONE organic load $\frac{\text{lb BOD}}{1000\ ft^3/\text{day}}$ design	AERATION ZONE organic load $\frac{\text{lb BOD}}{1000\ ft^3/\text{day}}$ actual	AERATION ZONE $\frac{\text{lb BOD}}{\text{lb MLSS}}$/day	AERATION ZONE detention time days	CLARIFIER surface overflow rate gal/ft^2/day	TOTAL SYSTEM detention time days
Salada Foods Ltd.	1.3	5.3	-	14	-	14
Skyline Farms Ltd.						
Actual	1.75	1.75	-	18.2	-	18.2
Proposed	8.25	8.25	4.13	4.5	1020	18.2
Nestle's (Canada) Ltd.	10.5	13.0	1.94	2.6	695	10.6
Cochrane	9.2	5.6	0.30	1.6	1670	7.8
Winona	5.0	5.1	1.48	25.8	43	38.6
Stobie Mine	7.0	1.7	0.54	0.95	435	1.07
Frood Mine	7.0	1.0	0.51	1.45	300	1.61
Murray Mine	7.0	3.9	1.21	1.15	580	1.27
Lively	NA	2.6	0.66	3.6	170	4.66
Levack	NA	3.7	0.80	2.2	190	3.24

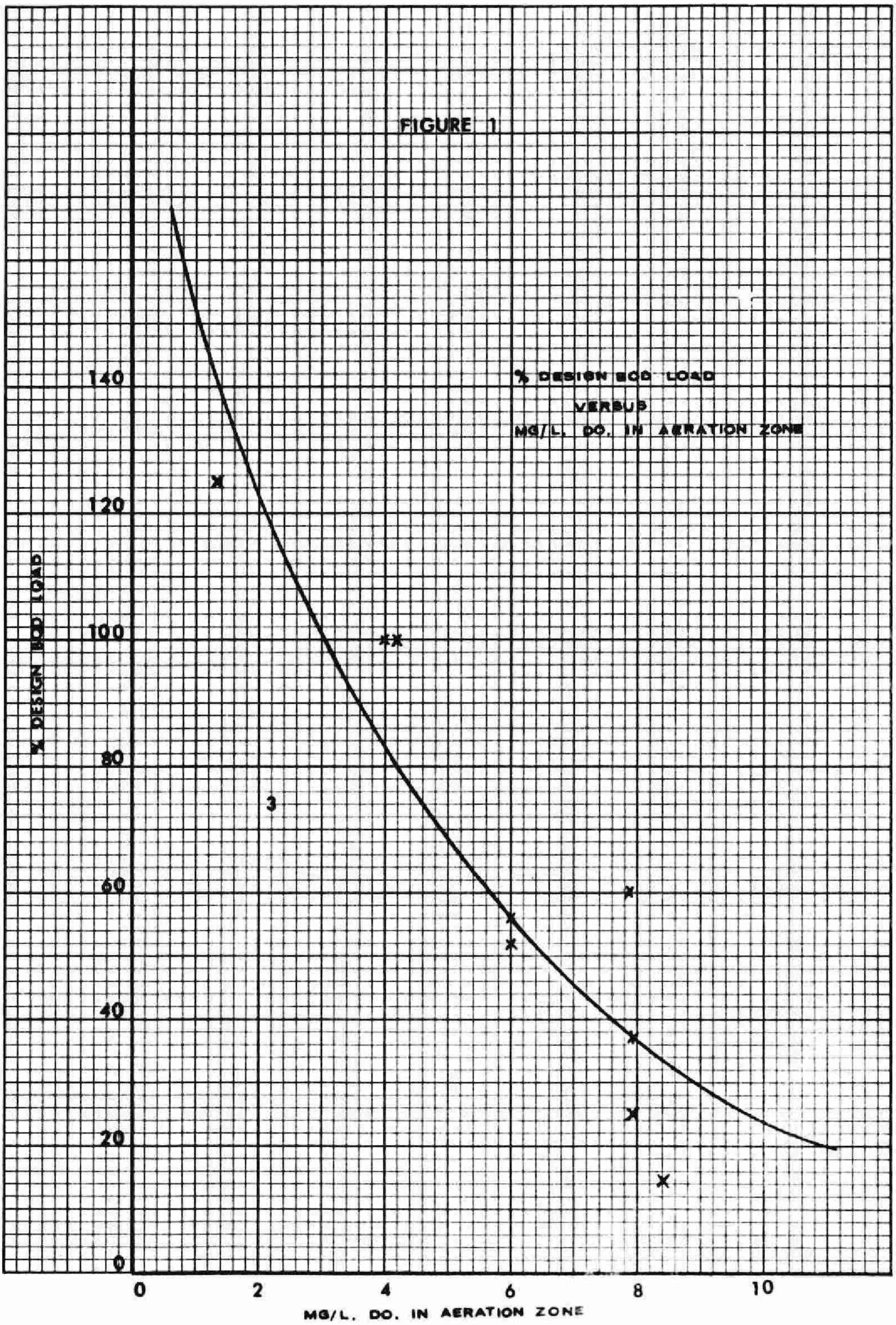
DISCUSSION OF RESULTS

The results from Skyline Farms Ltd. in Kettleby, show that when using a simple, single-stage, aerated lagoon on a relatively high strength waste, the effluent will not meet OWRC objectives. Even when using such a system on domestic sewage, it is expected that approximately 0.5 lb suspended solids will be produced per lb of BOD removed (4). This results in a minimum of 75 mg/l SS in the effluent, not considering the SS in the raw sewage.

Figure 1 shows that when the percent design BOD load is plotted versus the dissolved oxygen levels found in the aeration zones, a definite relationship is evident. From this figure, it can be concluded that the oxygen transfer design values used in these systems provide approximately 4 ppm DO in the aeration zone, when the system is loaded to 100 percent of its design load.

Previous studies have shown that the return sludge guns draw sludge from the bottom of the clarifier. Based on surface loading rates, with reference to Table IV, the clarifiers do not appear to be hydraulically overloaded. Thus the sludge return system should work provided the sludge has flocculant characteristics. The problem appears to lie with improper mixing.

FIGURE 1


% DESIGN BOD LOAD
VERSUS
MG/L. DO. IN AERATION ZONE
% DESIGN BOD LOAD
140
120
100
80
60
40
20
0
0
2
4
6
8
10
MG/L. DO. IN AERATION ZONE
3

In a biological waste treatment system which is designed to remove 8 lb BOD/1,000 cu ft/day, the BOD substrate must be intimately mixed with a recirculated activated sludge in order to effect 70 to 80 percent BOD removals. If this intimate mixing and recirculation does not take place, the system will operate as a simple aerated lagoon where the BOD substrate will be gradually synthesized to form biological solids. This rate of synthesis is relatively slow and would not normally approach the required percent removals in the designed retention time.

When this insufficient mixing occurs in such installations as Cochrane, the second or polishing zone becomes biologically overloaded and may produce odours.

A 6 to 8-minute turnover time, based on pumpage rates, is the maximum that can be tolerated in an extended aeration system. Several authors (5), (6) make brief statements with respect to the horsepower requirements for mixing which agree well with this figure.

Table III indicates that when considering the pumpage rates (no associated flow) of the aeration guns plus the return guns, we obtain turnover times in the range of 12.4 min to 28.3 min. This is obviously insufficient to maintain the biological solids in suspension.

Similarily, in the systems at Sudbury, Lively and Levack, the mixing requirements are not met if the guns are operated intermittently. If the guns run continuously, the mixing becomes marginal.

At the INCO sites, 80 to 90 percent of the hydraulic load occurs at the end of each shift over a total time period of 6 to 9 hr/day. This results in an extremely high hydraulic overload. In all the installations in the Sudbury area, high nickel concentrations of 2 to 3 mg/l in the raw sewage inhibit biological treatment.

In a system where mixing of the aerated media is required (i.e. activated sludge process or any simulation of this process) the pumping capacity of this aeration device must be considered. It was found that in all systems using lagoons as an extended aeration process, the number of aeration guns installed should have been based on the mixing requirements of the system. The oxygen requirements apparently were the only parameter considered when determining the number of guns required and this resulted in inadequate mixing and subsequent poor operation of these systems.

CONCLUSIONS

A turnover time of 7 min is the maximum allowable in extended aeration systems to ensure adequate solids suspension.

The systems at Cochrane, E. D. Smith and Sons Ltd., Winona, Nestle's of Canada Limited, Chesterville and the proposed system at Skyline Farms Limited, Kettleby, do not have sufficient mixing to provide adequate treatment at the ultimate design BOD load.

Intermittent operation of the Aero-Hydraulic gun results in operational problems due to plugging of the air inlet orifice and insufficient mixing in all systems investigated.

BIBLIOGRAPHY

1. Thon, J., "Oxygen Transfer Rate Determination", OWRC Report, November 17, 1964.

2. Boyko, B. I., "The Evaluation of the Aerobic Stabilization System at Skyline Farms Limited, Kettleby", OWRC Report, September, 1966.

3. Beak, T. W., "Report on Survey of Aero-Hydraulics Waste Treatment Facilities at Cochrane, Ontario", February, 1967.

4. Sawyer, C. N., "New Concepts in Aerated Lagoon Design and Operation", Advances in Water Quality Improvement, E. F. Gloyna, W. E. Eckenfelder Jr., University of Texas Press, 1968.

5. Williams, S. W. Jr., Hutto, G. A. Jr., "Treatment of Textile Mill Wastes in Aerated Lagoons", Pg. 525, 16th Industrial Wastes Conference, Purdue, 1961.

6. Eckenfelder, W. W., "Oxygen Transfer and Aeration", Manual of Treatment Processes, Volume I, Pg. 9.